Introduction to Botany. Lecture 20

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Outline

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Previous final question: the answer

Why plants need to avoid photorespiration?

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Why plants need to avoid photorespiration?

- To stop wasting of ATP and C_5
- To stop producing a toxic compounds
- To make photosynthesis better at high temperatures and light intensity

Results of Exam 2 (statistic summary)

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Summary:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
    0.0    52.0    61.0    61.3    74.0   107.0     3.0
Grades:
  F   D   C   B max
 49  58  66  74  82
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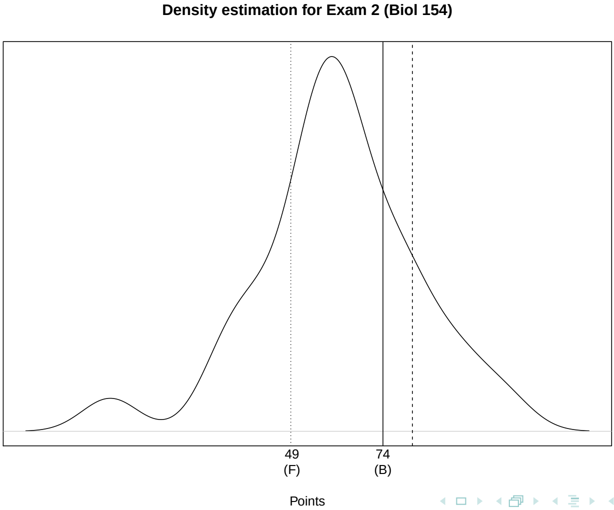
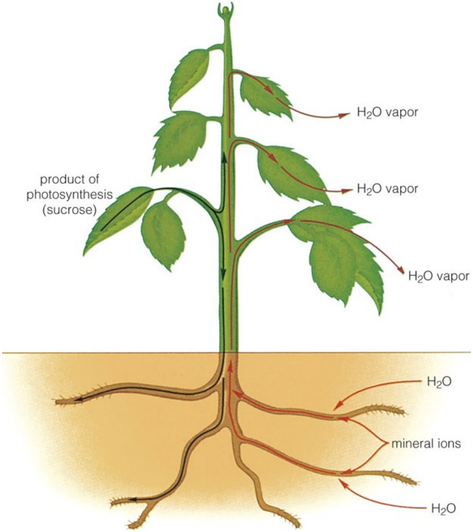
Results of Exam 2



Water transport

Water transport in roots

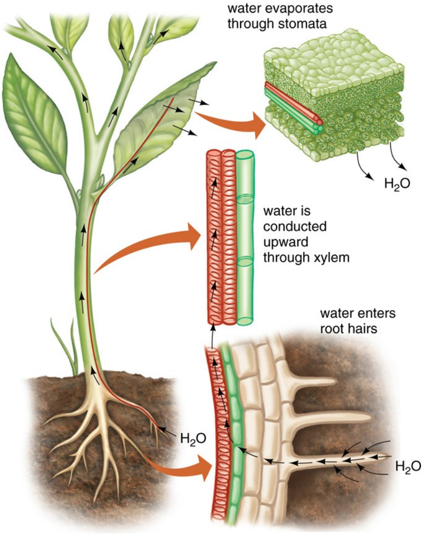
Overview of main flows inside a plant



General overview

- **Water**—from root hairs to leaf stomata via xylem
- **Mineral ions**—from root hairs to all plant organs via xylem
- **Sucrose** and other products of photosynthesis—from leaf mesophyll to all plant organs via phloem

Overview of water flow inside a plant



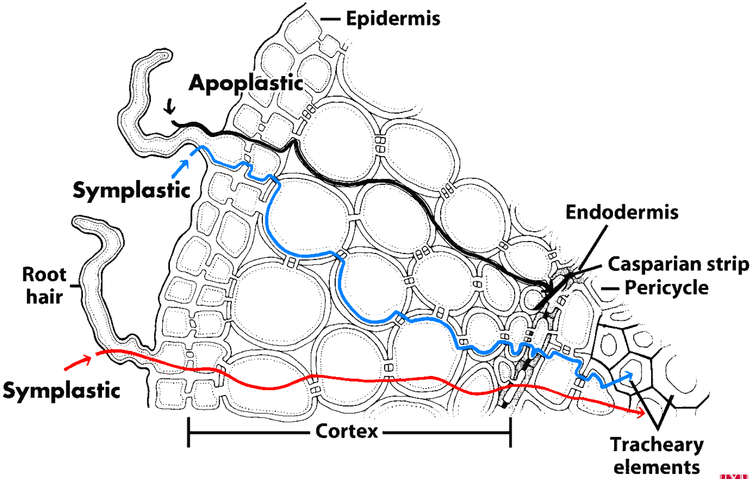
Rhizoderm and osmosis

- The existence of root hairs dramatically increases the surface of absorption
- Every root hair cell increase the internal concentration of large molecules, typically organic acids
- Process of concentration requires ATP
- As a result, osmosis water flow starts from soil to root cells

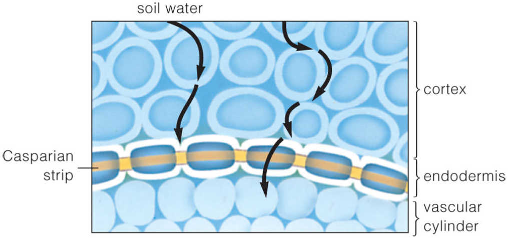
Endoderm and root pressure

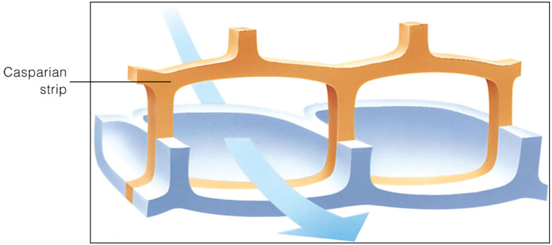
- From rhizoderm to endoderm, transport of water is both symplastic and apoplastic
- In the endoderm cells, Caspari stripes stop apoplastic transport and therefore forced symplastic transport
- This is a high-energetic process requires ATP
- As a result, water will be pushed up from root: this is the root pressure

Apoplastic and symplastic transport in the root

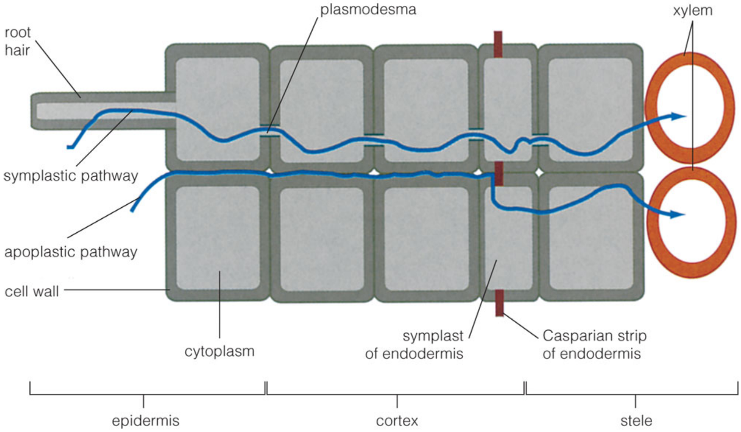


Casparian strips

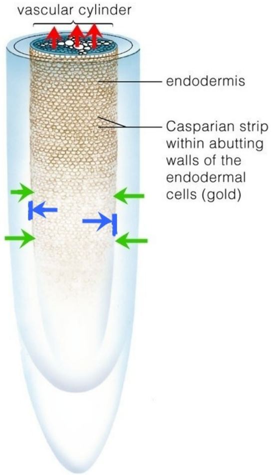




How Casparian strips are working



Origin of root pressure



Water potential

- **Water potential** is a virtual water pressure
- In plant, water always go from regions of higher water potential to regions with lower water potential

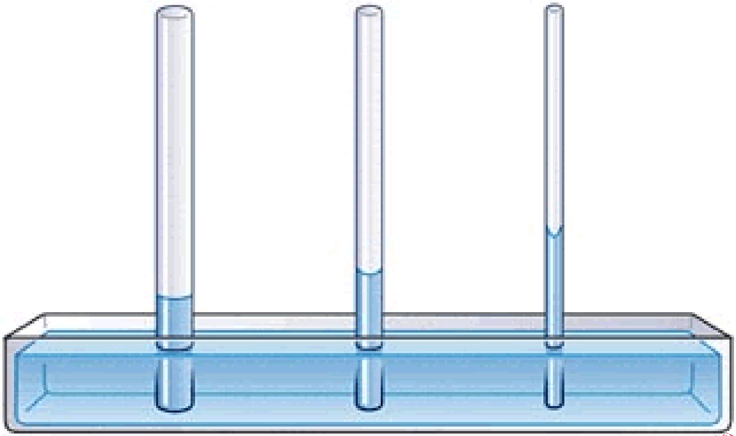
Water transport

Water transport in stems

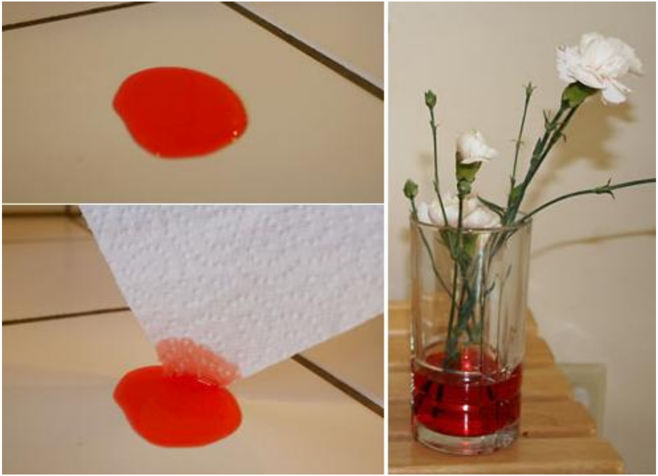
Water flow through xylem

- Continuous water flow through xylem is the result of capillarity—adhesion of water molecules to the walls of xylem vessel elements; and also cohesion of water molecules to each other
- As a result, pulling one water molecule from xylem will move all water molecules
- The more narrow vessel elements are, the higher is capillarity
- However, wide vessel elements could take much more water. As a result, there is a trade-off between wide and narrow vessel elements.
- Bubble in xylem cell will stop transport; tracheids have less chances to form bubbles than vessels

Capillarity



Experiment with capillarity



Water transport

Water transport in leaves

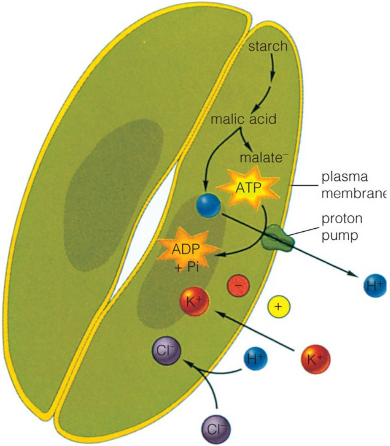
From vascular tissues to mesophyll

- Vascular bundles become leaf traces, and leaf traces become veins
- Vein xylem cells transfer water apoplastically to mesophyll cells

From mesophyll to stomata and leaf surface

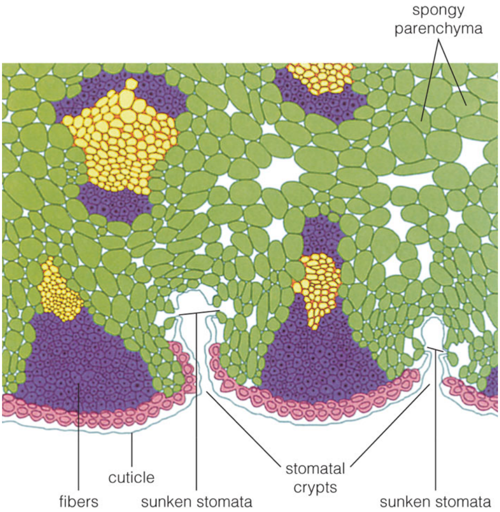
- Mesophyll cells and stomata control transpiration
- When stomata are open, water vapor constantly moves from the leaf causing other water molecules to follow
- Stomatal chambers, crypts and epidermis hairs will hold water because they provide spaces with higher humidity
- Common epidermal cells also transpire, even with cuticle. In stems, lenticels will transpire.

Opening and closing stomata

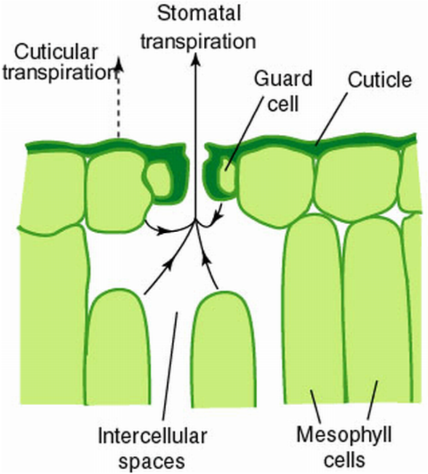


Stomata are opening when guard cells accumulate potassium (K^+) and malic acid (malate$^-$) ions which results in the osmotic flow inside guard cells, bloating of guard cells and finally opening of stoma.

Stomatal crypts



Transpiration



Guttation

When root pressure is too high, plant starts **guttation** (water droplets come through special openings which is much bigger than stomata, **hydatodes**)

Minerals
Primary and micro- elements

Primary (biogenic) elements

- Main three biogenic elements: carbon (C), hydrogen (H), oxygen (O): used as gases
- Slightly less important are nitrogen (N) and phosphorus (P) which are usually taken as anions: NH_4^+ or NO_3^- and HPO_4^{2-}
- Potassium (K), calcium (Ca), magnesium (Mg): used as cations, namely K^+, Ca^{2+}, Mg^{2+}
- Iron (Fe), sulfur (S): also used as ions, but in less amounts, typically as Fe^{3+} and SO_4^{2-}

Microelements

- Play a lesser roles and used in lesser amounts
- These are: manganese (Mn), boron (B), molybdenum (Mo), copper (Cu) , zinc (Zn) and chlorine (Cl)
- Microelements are also taken from the soil as ions
- Membrane of root cells have specific channels and pumps almost for every ion

Roles of some biogenic elements and microelements

Table 11.1 Roles of Mineral Elements in Plants

Element	Primary Roles
Potassium (K)	Osmotic solute, activation of some enzymes
Nitrogen (N)	Structure of amino acids and nucleic acid bases
Phosphorus (P)	Structure of phospholipids, nucleic acids, adenosine triphosphate
Sulfur (S)	Structure of some amino acids
Calcium (Ca)	Structure of cell walls, transmission of developmental signals
Magnesium (Mg)	Structure of chlorophyll, activation of some enzymes
Iron (Fe)	Structure of heme in respiratory, photosynthetic enzymes
Manganese (Mn)	Activation of photosynthetic enzyme
Chloride (Cl)	Activation of photosynthetic enzyme, osmotic solute
Boron (B), cobalt (Co), copper (Cu), zinc (Zn)	Activation of some enzymes

Nitrogen fixation

- Plants cannot take N_2 from air: it is an exceedingly stable molecule.
- However, some soil bacteria (nitrogen-fixing bacteria mostly from *Rhizobium* genus) can do that, they convert N_2 to ammonia (NH_4^+)
- Legume plants (Leguminosae, or Fabaceae), alders (*Alnus*) and members of silverberry family (like buffaloberry, *Schepherdia*) have root nodules inhabited with nitrogren-fixing bacteria.

Minerals

Soils

Soil types

- Every soil have (1) granular part like sand, (2) clay part (microscopic particles) and (3) humus part (decayed organic matter)
- The most important capacities of different soil types are: water-holding, aeration, pH (acidity), salinity/toxicity and biota
- Most soils have three layers (horizons): (A) topsoil, (B) subsoil and (C) parent material

Horizons of soil

Water flow through the soil

- Water moves through soil mostly via capillarity
- Compact, tough soil usually have high capillarity; loosen soil keeps water inside and do not transport it with capillarity

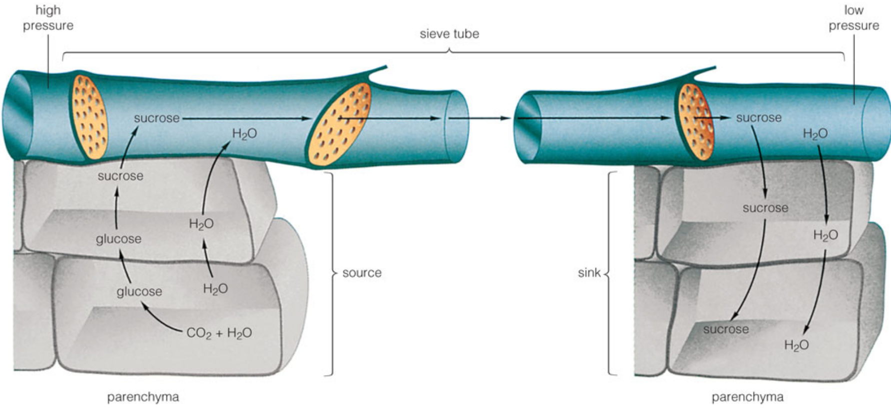
Transport of organic compounds

Phloem transport

Phloem osmotic pump

- Phloem transport is the result of osmotic pump from regions with higher concentration of sucrose to regions with lower concentration of sucrose
- Therefore, sucrose is transported only with water
- Phloem transport is purely symplastic
- As a consequence of above, phloem transport is usually much less directed than xylem transport

Phloem pump


high pressure
sieve tube
low pressure
sucrose
H_2O
sucrose
glucose
H_2O
glucose
H_2O
$CO_2 + H_2O$
source
sink
sucrose
H_2O
sucrose
H_2O
sucrose
H_2O
parenchyma
parenchyma

Summary

- Taking nutrients to roots is the result of **osmosis.**
- **Root pressure** is the result of forced symplastic transport (due to Caspari strips) in endoderm cells
- The height of trees is controlled mostly by the **capillarity** of xylem vessel elements
- **Water transport** in plants regulates by: (1) osmosis in root hairs, (2) root pressure in endoderm, (3) capillarity in vessels or thracheids and (4) transpiration in leaves
- Biogenic elements (except three gases) and microelements are taken from the soil as ions
- Phloem transport is the result of **osmotic pump**

Final question (2 points)

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What is guttation?

For Further Reading

J. E. Bidlack, Sh. H. Jansky.
Stern's introductory plant biology. 12th edition.
McGraw-Hill, 2011.
Chapter 9.

Th. L. Rost, M. G. Barbour, C. R. Stocking, T. M. Murphy.
Plant Biology. 2nd edition.
Thomson Brooks/Cole, 2006.
Chapter 11.